Wire Communication Aids to Air Transportation *

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RAPID development of air transportation in this country has continued through the past few years and today established routes connect nearly all important cities. The route mileage of the airways in the United States as shown in Fig. 1 totals over 30,000 miles. Regularly scheduled transport service is given on practically all of these routes and considerable use of them is also made by military and private planes. Statistics relating to service of air transport companies seem particularly significant. The United States Department of Commerce reported approximately 42,800,000 miles flown in passenger, mail and express service on domestic scheduled lines in 1931, an increase of 35 per cent over the preceding year and more than a fourfold increase since 1928. In the same three-year period passengers carried increased ninefold, reaching a total of around 470,000 in 1931. Along with this growth safety has been increased as indicated by the respective 1928 and 1931 reports of 250,000 and 750,000 miles flown per accident. Reasonable regularity of schedules on air transport lines also has been maintained, the ratio of miles actually flown to scheduled miles last year being in the order of 92 per cent.

Communication facilities have been an important contributing factor to all this development and improvement. It was recognized early that fast and reliable communication would be needed in connection with any extensive development of air transportation. Communication with planes in flight was an obvious requirement and this could be provided only by radio. For land service, however, experience has indicated that wire facilities best meet the general requirements. This paper describes the wire communication facilities in general use today, both by the Government and by transport companies, as aids to air transportation.

Principal airways have been established largely through Federal aid. In addition to marking and lighting airways the Airways Division of the Department of Commerce had provided up to April 1, 1932, 67 radio telephone stations at approximately 200-mile intervals as indicated in Fig. 1, to be used for broadcasting weather reports and similar

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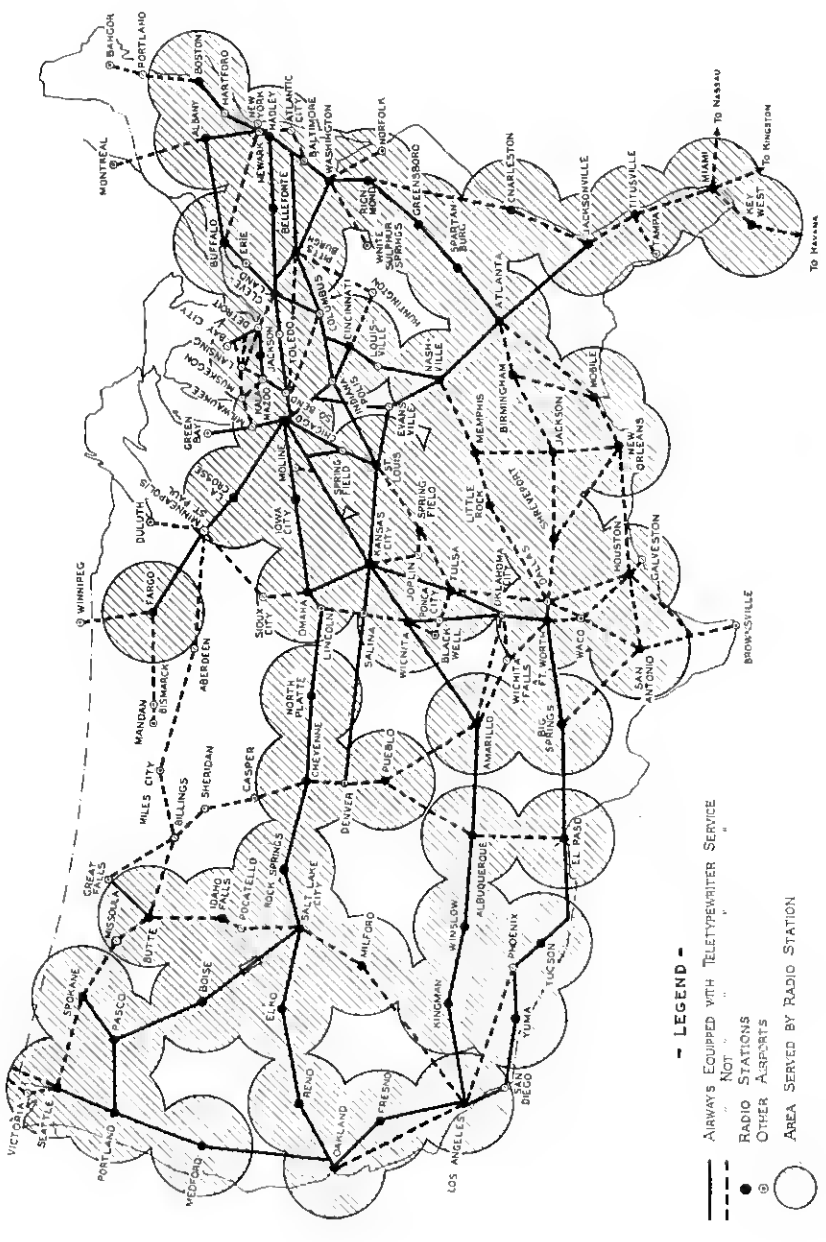

Fig. 1—Airway map of the United States showing routes equipped with teletypewriter service.

information to planes in flight and for transmitting directive radio beacon signals for enabling planes to keep on the course. In conjunction with these services it had contracted for 24-hour teletypewriter service along 13,000 miles of main airways connecting some 250 stations, principally for the purpose of transmitting weather reports and to assist in dispatching the planes. All of these facilities have been made available without cost to aircraft operating companies and others using the airways.

In addition to this communication service contracted for by the Government, approximately 5,000 miles of teletypewriter circuit are used daily in furnishing private wire communication service to a number of transport companies for transmitting information pertaining to the operation of their own lines. Routes on which these facilities are furnished to the Government and transport companies are indicated by heavy lines in Fig. 1.

When the first air mail service was established, radio telegraph was introduced as a means of point-to-point communication along the New York-Chicago-San Francisco airway route. At each radio station meteorological data were collected from surrounding points by means of long distance telephone and telegraph and these data were exchanged periodically through the day with the other stations over the radio telegraph.

With a rapid expansion in air transport service foreseen it was apparent there would be a large increase in communication requirements not only to equip new routes but to handle increased volume on existing routes. There was the definite requirement for radio telephone communication with planes which would need a number of the radio channels allotted to this service. Considering these factors and the geographic and other conditions applying to probable development of air transportation in the United States, it seemed that regular point-to-point service served by radio telegraph could be provided more satisfactorily in another way.

Arrangements were made in 1928 for teletypewriter communication services at several points connecting radio stations with their local weather bureau offices in order to expedite the delivery of weather reports and other traffic handled by radio telegraph. Shortly afterward, a teletypewriter system was installed on the New York-Cleveland route connecting the Department of Commerce and Weather Bureau stations at Hadley Field, Stelton, N. J., and Cleveland, Ohio, and a number of intermediate points. This type of service seemed ideally fitted for use in weather reporting and plane dispatching and has been extended not only to replace the service furnished by the radio telegraph system but also to provide for communication requirements on other routes.

Teletypewriter service offers the advantages of simultaneous communication with any desired number of stations, the communications being automatically recorded on machines at each point. A message using code or abbreviations, if desired, can be sent instantly without the necessity of calling in or checking with the receiving stations; thus the immediate attention of only the sending operator is required. Automatic recording reduces the possibility of human error and permits the most efficient use of operating personnel with resulting savings in labor. Furthermore, as contrasted with radio, this system, utilizing wire transmission, is not so subject to variations in meteorological conditions; it is thus more dependable, and has the advantage that it can be readily extended to handle large volumes of business. This system also is well adapted for carrying on administrative and other work as well as for weather reporting and plane dispatching.

Transmission of Weather Reports

Material progress has been made in reducing the effect of weather hazards to air transportation, through the service rendered by the Department of Commerce and United States Weather Bureau in the collection and dissemination of weather reports supplemented by other reports collected by individual transport companies from planes in flight. For this service a system of practically continuous reporting and forecasting for areas along air routes has been developed and weather observations have been extended to include data of particular benefit to air navigation.

The teletypewriter networks furnished the Department of Commerce are devoted largely to this purpose and in conjunction with its radio telephone broadcasting service are the means for providing to pilots information relating to existing conditions and forecasts for both general and local areas.

Twelve selected Weather Bureau airport stations located at strategic points in the country's airway network prepare summaries of weather conditions in their own areas and make area forecasts every three hours based on data collected over the Department of Commerce circuits from connected airway stations and over commercial telegraph lines from other reporting points. These summaries and forecasts are then transmitted over the teletypewriter circuits and made available to all airway stations.

While the forecasts include predictions as to storm developments or movements, conditions in specific localities are often likely to change rapidly and it has been necessary to provide additional reports along the air routes on an hourly basis in order to keep pilots continuously

advised of conditions likely to be encountered. Consequently, the airway keepers and Weather Bureau observers at the various teletypewriter stations make local observations of general weather conditions, ceiling height, visibility, wind direction and velocity, temperature, and barometric pressure, every hour. These data are then sent by teletypewriter and automatically recorded at all points in accordance with a predetermined schedule, which is coordinated with the broadcast schedule of radio stations. Since pilots will tune in on particular stations at definite times to obtain reports in accordance with the broadcast schedule, it is important that the schedules be closely adhered to. The following is an illustration of scheduled weather reporting along the Newark-Cleveland route.

At 42 minutes past the hour the observers will begin typing their observations on the circuit beginning with the Newark station, followed successively by Hadley, Allentown, Park Place, Numidia, Sunbury, Winkleblech, Bellefonte, Kylertown, Greenwood Club, Brookville, Mercer, Parkman and Cleveland, with practically no interval between the completion of the report from one station and the beginning of a report from the next. When the Cleveland weather observer has completed typing his report a complete record of weather conditions at all points on the circuit will appear on the teletypewriter tape at each individual station and in the radio broadcasting stations located at Hadley, Bellefonte and Cleveland. Fig. 2 shows a portion of an

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NK CV 0642ES
NK OVC LWR BRKN CLDS OCNL SPRKG ETD 6 HND 2 1/2 NE 8 42 40 3010
HW OVC LWR BRKN CLDS SPRKG HAZY 1 THSD 3 NE 5 42 3006
AL OVC LT RAIN LT FOG ETD 6 HND 2 E 10 41 3006
PL DENSE FOG LT RAIN ZERO ZERO ESE 15 37 3006
NU OVC LT RAIN HAZY ETD 1 THSD 3 E 12 41
SV OVC LT RAIN LT FOG ETD 12 HND 1 NE 9 43
WK DENSE FOG LT RAIN ZERO ZERO E 18 37 3004
BF OVC LT RAIN 8 HND 6 NE 6 43 43 2998
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Fig. 2—Teletypewriter tape with portion of weather sequence report.

actual tape record of an hourly report along the Newark-Cleveland route which includes the stations between Newark and Bellefonte, Pa. For convenience the tape has been cut to show one station report on

each line. First the starting time, 0642 E. S., which is 6:42 a.m. Eastern Standard Time, is shown. Each reporting station in sequence then gives its code letter or letters and follows with a report of its observations. An interpretation of the report from the first station is "Newark, overcast, lower broken clouds, occasional sprinkling, estimated ceiling height 600 feet, visibility 2½ miles, wind velocity 8 miles per hour, direction northeast, temperature 42°, dew point 40°, barometric pressure 30.10 in." The time of actual transmission for all 14 stations, Newark to Cleveland, is generally about four minutes.

At 50 minutes past the hour the three radio stations will interrupt the beacon signals and broadcast the reports just received. Hadley station transmits the weather sequence received from stations between Newark and Bellefonte; simultaneously, the Bellefonte radio station transmits the entire sequence received from all points between Newark and Cleveland, and the Cleveland radio station broadcasts reports from points between Bellefonte and Cleveland. All three radio stations include in the sequence, reports of weather at Cleveland and New York. The range beacons are not interrupted for these reports for longer than two minutes, and if the reports require a longer period the beacon signals are restored for one minute and again interrupted to complete the reports.

Based upon the information obtained through the sequence collections, the airway weather reporting station retransmits, generally by teletypewriter, hourly weather reports to the various airway operating companies' offices in that vicinity. Airway companies maintain various arrangements for posting the weather information for the convenience to pilots. Some companies post the information on a series of boards of different color arranged in geographic sequence to represent different airway routes, each board indicating a particular point on that route.

An experimental service involving the transmission of weather summaries in map form has been tried out recently at Kansas City, Chicago, Cleveland, Newark and Washington. A separate circuit equipped with page teletypewriters at each of these points was provided for this purpose. The weather maps were prepared at Kansas City and Cleveland every three hours. A typical map, the notations of which were transmitted over the circuit and directly printed by the teletypewriter, is shown in Fig. 3, and the following describes briefly the methods used.

Two special airways maps, ordinary letter width, have been printed, one map covering the section of the country east of the Mississippi River and another the section west to the Rocky Mountains. The maps are printed in ink which permits hectographic reproduction. The

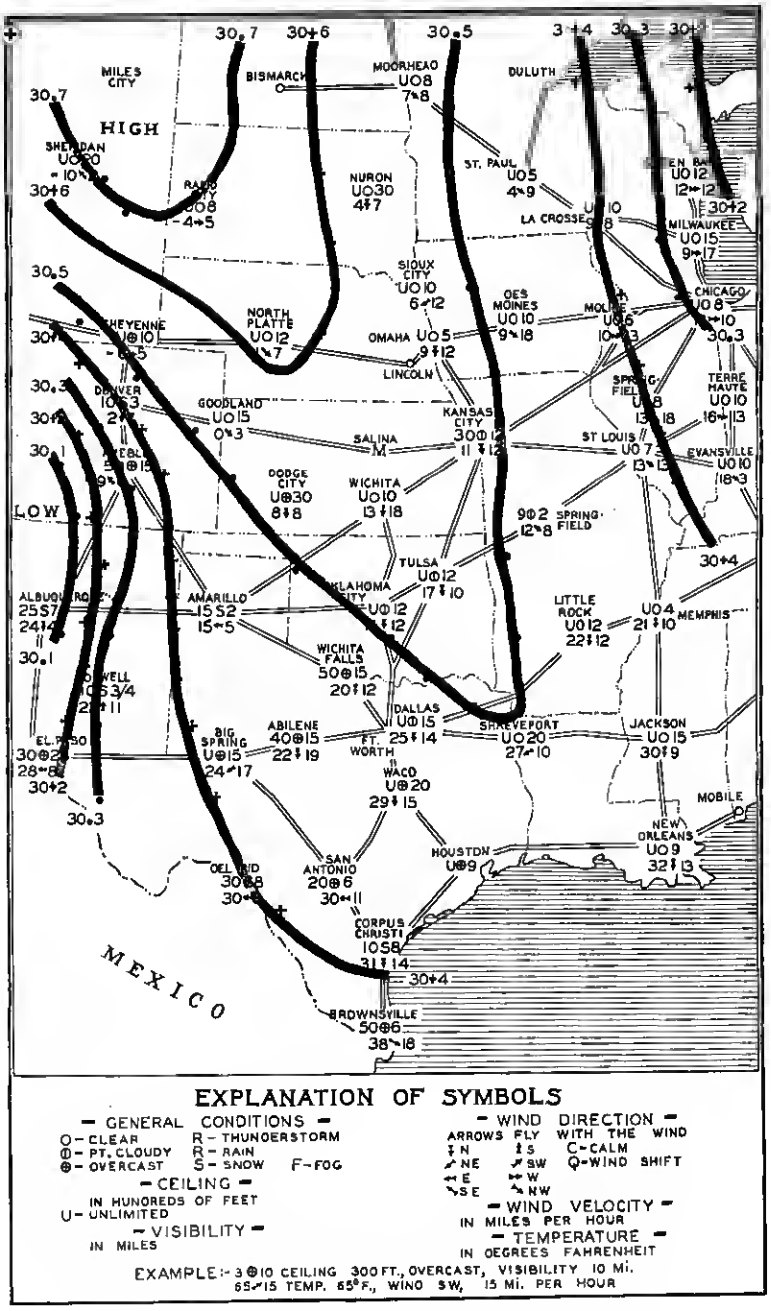

Fig. 3—Weather map, the notations of which were transmitted and directly printed by the teletypewriter system.

airways, principal airports, and cities are shown on the map and in the upper left corner is a small circle used as a coordinating point.

At a scheduled time the operator at Kansas City or Cleveland inserts in a teletypewriter equipped for perforating tape a copy of the map on which the latest weather information has already been typed including general state of weather, ceiling height, visibility, temperature, wind direction and velocity and barometric pressure for each point and isobars connecting points of equal pressure. The sending operator then types the identical symbols, letters, and figures directly over the corresponding ones on the map inserted in his machine, thus making a complete record on perforated tape. On schedule a blank map is inserted in the teletypewriter at each receiving point and positioned so that a type bar will strike the map within the small coordinating circle. The sending operator then releases the tape and the signals transmitted over the circuit reproduce on the map at the receiving stations data similar to those on the original map at the sending station.

The map data are sent in sequence from the two transmitting stations and after they have been received on the map forms a number of duplicate copies can be run off immediately and the two maps fitted together if desired. The maps are then available to pilots at each of the respective airports.

Complete reports of weather are generally maintained by transport companies in dispatching offices. On some lines two-way short-wave radio telephone equipment has been provided for communicating with planes and periodic contact is maintained during flight. In this way pilots report their positions directly to dispatchers and in addition supplementary weather data are usually exchanged, particularly in respect to local ceiling heights and conditions in the upper air strata.

Plane Dispatching and Other Service

Teletypewriter circuits furnished to air transport companies are used principally for dispatching planes and handling the many traffic matters usual to this type of service. Plane movements including reports of position in flight are transmitted over the teletypewriter system and recorded at various offices. The reports of positions, in many cases, are given by pilots over short-wave radio telephone where this type of equipment has been provided.

To facilitate position reporting some of the companies have superimposed a system of rectangular coordinates over a map of the course cutting the territory into squares or rectangles 10 to 20 miles on a side. The coordinates are numbered so that the pilots and dispatchers can

readily establish the location of the plane. The dispatchers generally maintain a typewritten, chronological log of position reports from each plane in the air. Bulletin boards are also used, marked with the stations along the route and with spaces for filling in data such as plane number and license, name of pilot, time of arrival and departure at each station and final destination.

A considerable volume of information is required to be transmitted in connection with the handling of traffic on large lines. This usually consists of data as to reservations, number of passengers and amount of mail and express carried, connections to be made, and arrangements at terminals. Supplementary instructions to pilots and many administrative matters requiring prompt handling are also transmitted.

Although the airways teletypewriter circuits furnished the Department of Commerce are used mostly for handling weather reports, considerable information is also transmitted over them relating to departure and arrival of planes and their position in flight. Upon request the Department of Commerce will send over its teletypewriter system the license number of a plane, the station from which the plane is departing, its time of departure, and its destination, to stations along the route of the flight. Stations on the route knowing approximately the time the plane will be due watch for it and record the actual time the plane passes so that other stations may be informed.

Teletypewriter Circuit Layout

Teletypewriter networks furnished by the Bell System for service along airways are composed of some 30 separate circuits. Circuit mileage of the longest is about 2,000 miles and of the shortest, 200 miles. The longer circuits generally connect 15 to 20 intermediate stations. Since airways naturally follow direct air lines the intermediate airway stations are often located at points considerable distances from main communication lines, which, generally, are constructed along routes connecting the industrial and more populous centers, due regard being given to topographic and other conditions. At the larger airports such as Newark and Cleveland, local teletypewriter circuits are also provided to connect the Department of Commerce station with the offices of the various transport companies, the post office, and weather bureau. Automatic transmission equipment is provided so that information received on one circuit can be retransmitted over one or more other circuits if desired.

A layout diagram of a typical circuit is shown in Fig. 4. Facilities in the New York-Cleveland long distance cable are used for establishing the main links totaling 515 miles. Repeater stations on the cable

route located approximately every 50 miles afford convenient points from which branch circuits are extended to the intermediate airway stations. The several branch circuits are of the grounded open-wire

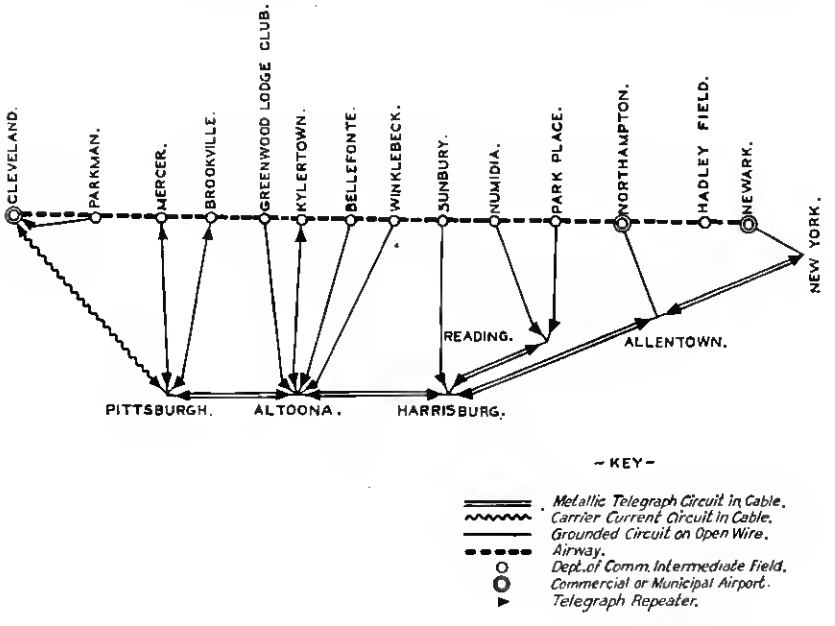

Fig. 4—Layout of typical teletypewriter circuit along airway.

type and total 331 miles. A total circuit mileage, therefore, of 846 miles is required in this case for connecting all stations along an air route a little over 400 miles long.

The Newark-Pittsburgh section of the main circuit is operated on metallic telegraph cable facilities, a type particularly adapted to use where stations to be connected to the circuit are spaced at frequent intervals. Between Pittsburgh and Cleveland a channel of a voice frequency carrier telegraph system on cable facilities is used. This type of facility is generally used where stations are located 150 or more miles apart. The longer branch circuits on open wire employ polar transmission with repeaters at both the repeater station and terminal and use two wires, one for each direction of transmission. The shorter branch circuits use one wire with a grounded duplex repeater at the repeater station and a constant d.c. potential at the outlying terminal. Detail descriptions of these various telegraph systems have been given in previous papers.

Cable circuits are less susceptible than open-wire circuits to inter-

ference and storm trouble, and where they are available they have been used generally for establishing teletypewriter circuits furnished both the Department of Commerce and the transport companies. At present, over one third of the mileage of these circuits is in cable. Facilities on alternate routes are available to be substituted for the regular circuit in the event circuit trouble develops.

Teletypewriter Equipment

The theory of teletypewriter operation and descriptions of the machines generally used in this country have been given in other papers but are briefly reviewed here in order to describe some of the specific equipment arrangements used in airways service.

The teletypewriter is designed to perform the functions of an ordinary typewriter with added features that permit the typing units of a number of similar machines located at distant points to be controlled by the operation of the keyboard of any one of them. This is accomplished by the translation of the mechanical action of any key in the keyboard unit to electrical impulses arranged in a code and transmitting them over an electrical circuit to the distant machines where the impulses are translated back to the mechanical action of a type bar in the typing unit corresponding to the key struck in the distant keyboard. Electric motors and electro-magnets provide the mechanical power and the means of translation of electrical impulses to mechanical action. It is necessary, of course, that the mechanical action of all of the machines be synchronized. This is provided for by the use of synchronous motors or governed motors regulated to the same speed and a start-stop rather than a continuously rotating system. By the use of the start-stop system the effect of variations in motor speeds is minimized, accurate synchronization being required only during the interval of typing of one letter after which a clutch releases and stops the receiving mechanism momentarily to permit it again to start in synchronism with the sending mechanism. To provide the start-stop feature and sufficient code combinations for the letters and symbols required a seven-impulse code is used consisting of a start pulse, five selecting pulses, and a stop pulse.

Teletypewriters are available to print on an ordinary page or on a narrow strip of tape. Tape machines are generally used in airways service because they are particularly adapted to the handling of short messages and weather sequences where it is generally desirable to rearrange the messages received by cutting and pasting the tape on separate pages to form a continuous weather record for each point. This is preferable to a chronological message record requiring a search

through all of the information to obtain the trend of weather at a particular point. The tape machines are also somewhat smaller, less expensive, and more efficient, not requiring the transmission of carriage return and paper feeding signals.

In addition to the ordinary sending and receiving machines supplementary apparatus units may be used so that operators can work at maximum efficiency and the line circuit can be used to its maximum capacity. These units are the perforator, tape transmitter, and reperforator.

Fig. 5—Department of Commerce airport teletypewriter station.

The perforator is associated with a keyboard and perforates a tape with one to five perforations for each key struck. The tape is run through a tape transmitter which automatically sends electrical impulses to the circuit corresponding to the perforations in the tape and identical to those that would have been sent from the keyboard direct had it been connected to the circuit for normal keyboard sending. The use of the perforator and tape transmitter permits the circuit to be

operated at its maximum speed at all times and permits the operator to do other work while the accumulated tape is running through the transmitter. Also the same tape can be run through several tape transmitters and thus be used for sending the message over several circuits.

The reperforator is a receiving device which records the message on a perforated tape similar to that produced by a perforator unit. This permits storing a received message for immediate or subsequent retransmission to other circuits without retyping it.

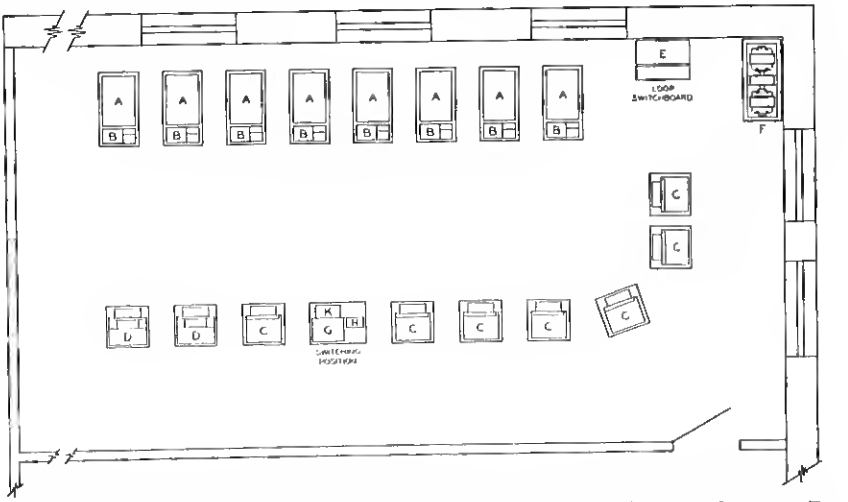

Fig. 6—Teletypewriter equipment layout in large office. *A*, Reperforator; *B*, Transmitter distributor; *C*, Tape teletypewriter; *D*, Page teletypewriter; *E*, Loop switchboard; *F*, Motor generator set; *G*, Radial transmitting board; *H*, Remote control box; *K*, Perforator.

The smaller teletypewriter stations of the Department of Commerce and those of the various transport companies are generally provided with one or two teletypewriters. At the larger teletypewriter stations of the Department of Commerce a special arrangement of the equipment has been provided to permit efficient operation of the teletypewriter circuits from the standpoints of requiring the fewest operators and of obtaining rapid retransmission of messages received on one circuit to one or more of the other circuits as required. A view of an installation is given in Fig. 5 and a typical floor plan arrangement is illustrated in Fig. 6. The apparatus is mounted on tables specially designed for the purpose, and these are usually arranged on the floor in the shape of a U, the units facing inward so that the operators work inside the U.

A separate reperforator (*A*) and tape transmitter (*B*) in addition to a tape teletypewriter (*C*) are provided for each circuit. Messages are received simultaneously on a printed tape by the tape teletypewriter and on a perforated tape by the reperforator. Mounted adjacent to the reperforators are the tape transmitters through which the perforated tape can be run to retransmit immediately a received message to another circuit. The reperforators and tape transmitters can be started and stopped individually from the remote control box (*H*).

A tape perforator (*K*) is provided to perforate tape for messages originating at the local station. The messages can then be sent automatically over the circuit or circuits desired by running the tape through the proper tape transmitters.

All of these units are terminated on cords and plugs at a loop switchboard (*E*) and any unit or combination of units may be connected to any of the teletypewriter circuits which are wired through a number of series jacks in the loop switchboard. A supplementary switching arrangement is provided by radial transmitting board (*G*) equipped with keys and repeating relays. By operating one or more of the keys one of the tape transmitters can be connected quickly to two or more of the teletypewriter circuits through the repeating relays to obtain simultaneous transmission to the circuits connected.

At certain stations page teletypewriters (*D*) are provided for the transmission of weather maps as described previously. This type of machine employs a fixed paper carriage and movable type basket, and accommodates paper up to 8½ inches wide. It has been equipped with a number of special type characters to provide the symbols required on the maps. These symbols, which are shown in Fig. 3, are provided as upper case characters on the teletypewriters in place of fractions and punctuation marks.

The arrangement of equipment described generally permits one operator to attend all of the circuits. The teletypewriters are all located in a fairly small space, which permits one man to observe the incoming messages and operate the control boards, to start and stop the proper transmitter and to relay the messages as required.

Radio Interference

The establishment of teletypewriter stations along the airways brought about the installation of teletypewriter equipment in the same room or in close proximity to short-wave radio receivers, and introduced the problem in specific cases of radio interference caused by the operation of the teletypewriter.

Remedial measures have been designed effectively to reduce this

interference, and consist of the use of synchronous motors, rectifiers and specially designed filters, together with the locating of the apparatus and wiring in such a way as to effect a minimum coupling between the teletypewriter and its associated loop and the radio antenna system.

Conclusion

History of air transportation in the past few years indicates that continued growth may be expected, particularly as hazards to flying are mitigated and safety and dependability are recognized by the public. The Government is continuing the extension of airways and weather reporting and other services, and air transport companies are progressing in developing transport business. Fast and reliable communication service has proved the backbone of weather and position reporting and has been a valuable aid in the handling of traffic and other matters relating to air transportation. Teletypewriter circuits used for land service have been found particularly suited to meeting the various requirements involving simultaneous communication with many stations at remote distances. Other wire communication services such as long distance telephone and commercial telegraph have also aided, particularly in reaching points not served by teletypewriter circuits. It is expected wire communication service will continue to be used extensively in connection with air transportation and will be of considerable aid in its future development.

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